

CLAIMS

1. A chemical or biochemical reactor comprising:
a reaction unit including a chamber having a volume of less than 1 ml, an inlet to
5 the chamber connectable to a source of a chemical or biological starting material, and
an outlet of the chamber for release of a product of a chemical or biological reaction
involving the starting material; and
a collection chamber connectable to the outlet of the reaction chamber, the
collection chamber having a volume of greater than 1 liter.
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2. A reactor as in claim 1, the reaction chamber having a volume of less than about
100 microliters.
3. A reactor as in claim 1, the reaction chamber having a volume of less than about
15 10 microliters.
4. A reactor as in claim 1, the reaction chamber having a volume of less than about
5 microliters.
- 20 5. A reactor as in claim 1, the reaction chamber having a volume of less than about
1 microliter.
6. A reactor as in any preceding claim, wherein the reaction unit comprises an
etched portion of an article.
- 25 7. A reactor as in claim 6, wherein the reaction unit chamber comprises etched
silicon.
8. A reactor as in any preceding claim, wherein the collection chamber comprises
30 etched silicon.

9. A reactor as in any preceding claim, further comprising a mixing unit fluidly connectable to the inlet of the reaction chamber.
10. A reactor as in claim 9, the mixing unit including an outlet connectable to the inlet of the reaction chamber, a plurality of inlets each in fluid communication with the outlet and a mixing chamber between plurality of inlets and of the outlet.
11. A reactor as in claim 10, wherein the mixing unit chamber is free of active mixing elements.
12. A reactor as in claim 11, wherein the mixing chamber is constructed and arranged to coalesce a plurality of reactant fluids provided through the plurality of inlets and to cause turbulence in the fluids thereby mixing and delivering a mixture of the reactant fluids through the outlet of the mixing chamber.
13. A reactor as in claim 12, wherein the mixing unit includes a fluid flow path between the plurality of inlets and the outlet and a plurality of obstructions in the flow path constructed to cause mixture of fluid flowing through the flow path.
14. A reactor as in any of claims 9-13, wherein the mixing unit is attachable to and separable from the reaction unit.
15. A reactor as in any of claims 9-14, wherein the mixing chamber includes a volume, between the plurality of inlets and the outlet, of less than 1 liter.
16. A reactor as in any of claims 9-14, wherein the mixing chamber includes a volume, between the plurality of inlets and the outlet, of less than 10 microliter.
17. A reactor as in any of claims 1-8, further comprising a heating unit having an inlet, and an outlet connectable to the inlet of the reaction chamber, the heating unit separable from and attachable to the reaction chamber.

18. A reactor as in any of claims 1-8, further comprising a heating unit having an inlet, and an outlet fluidly connectable to the inlet of the reaction chamber, the heating unit separable from and attachable to the reaction chamber.
- 5 19. A reactor as in claim 18, wherein the heating unit includes an inlet, and a plurality of outlets fluidly connected to the inlet.
20. A reactor as in any of claims 1-8, further comprising a heating and dispersion unit having an inlet, and an outlet connectable to the inlet of the reaction chamber, the heating and dispersion unit separable from and attachable to the reaction chamber.
- 10 21. A reactor as in claim 20, wherein the heating and dispersion unit includes an inlet and a plurality of outlets connected to the inlet.
- 15 22. A reactor as in claim 21, further comprising a mixing unit having a plurality of inlets communicating with a mixing chamber, the mixing chamber communicating with an outlet, wherein the outlets of the heating and dispersion units are connectable to the inlet of the reactor, and the inlet of the heating and dispersion unit is connectable to the outlet of the mixing unit.
- 20 23. A reactor as in any of claims 18-22, wherein the dispersion unit is constructed and arranged to maintain fluid exiting the unit through the plurality of outlets at a temperature of approximately 30°C.
- 25 24. A reactor as in any preceding claim, wherein the reaction chamber is constructed and arranged for cell cultivation.
25. A reactor as in claim 24, wherein the reaction chamber has a surface adapted for immobilization of cells.
- 30 26. A reactor as in any preceding claim, further comprising a separation unit having an inlet and an outlet, the inlet connectable to the outlet of the reaction chamber.

27. A reactor as in claim 26, wherein the separation unit is connectable to and removable from the reaction chamber.
- 5 28. A reactor as in either of claims 26 or 27, wherein the separation unit includes an inlet connectable to the outlet of the reaction chamber, a carrier fluid outlet, a fluid pathway connecting the inlet with the carrier fluid outlet, and a size-selective membrane positioned to contact fluid flowing from the inlet to the fluid carrier outlet.
- 10 29. A reactor as in claim 28, wherein the membrane has a first side positioned to contact fluid flowing from the inlet to the fluid flow outlet and an opposing second side defining in part a product extraction solvent flow pathway.
- 15 30. A reactor as in either of claims 28 or 29, wherein the carrier fluid outlet is connectable to a recovery container for recycling of reaction carrier fluid.
31. A reactor as in any preceding claim, further comprising at least one sensor of temperature, pH, oxygen concentration, or pressure.
- 20 32. A reactor as in claim 31, comprising sensors of each of temperature, pH, and oxygen concentration.
- 25 33. A reactor as in any preceding claim, including a plurality of reaction chambers, attachable to and separable from each other, constructed and arranged to operate in parallel.
34. A reactor as in claim 33, comprising at least 10 reaction chambers constructed to operate in parallel.
- 30 35. A reactor as in claim 33, comprising at least 100 reaction chambers constructed to operate in parallel.

36. A reactor as in claim 33, comprising at least 500 reaction chambers constructed to operate in parallel.
37. A reactor as in claim 33, comprising at least 1,000 reaction chambers constructed to operate in parallel.
38. A reactor as in claim 33, comprising at least 10,000 reaction chambers constructed to operate in parallel.
39. A method comprising:
carrying out a chemical or biological reaction in a plurality of reaction chambers operable in parallel, each reaction chamber having a volume of less than 1 ml; and
discharging product of the reaction from the plurality of reaction chambers simultaneously into a collection chamber having a volume of greater than 1 liter.
40. A method as in claim 39, wherein the reaction is one of cell cultivation, catalysis, pharmaceutical production, hazardous chemical production, or chemical remediation of warfare reagents.
41. A method as in claim 40, wherein the reaction involves cell cultivation.
42. A method as in claim 41, involving passing a feedstream across immobilized cells and recovering a protein product in the collection chamber.
43. A method as in any of claims 39-42 comprising carrying out the chemical or biological reaction in parallel in at least 10 reaction chambers, and discharging product from each of the reaction chambers into the collection chamber.
44. A method as in any of claims 39-42 comprising carrying out the chemical or biological reaction in parallel in at least 100 reaction chambers, and discharging product from each of the reaction chambers into the collection chamber.

45. A method as in any of claims 39-42 comprising carrying out the chemical or biological reaction in parallel in at least 500 reaction chambers, and discharging product from each of the reaction chambers into the collection chamber.
- 5 46. A method as in any of claims 39-42 comprising carrying out the chemical or biological reaction in parallel in at least 1,000 reaction chambers, and discharging product from each of the reaction chambers into the collection chamber.
- 10 47. A chemical or biochemical reactor system comprising:
at least ten individuated chemical or biochemical reactors constructed and arranged for operation in parallel, and seperable to a non-parallel operative state and re-attachable to each other for operation in parallel , each including a reaction chamber having a volume of less than 10 ml.
- 15 48. A chemical or biochemical reactor system comprising:
a mixing chamber including a plurality of inlets connectable to a plurality of sources of chemical or biochemical reagents and an outlet;
a reaction chamber connectable to and removable from the mixing chamber, the reaction chamber having a volume of less than 1 ml, an inlet to the chamber
20 connectable to and removable from the outlet of the mixing chamber, and an outlet of the chamber for release of a product of a chemical or biological reaction involving the starting material.